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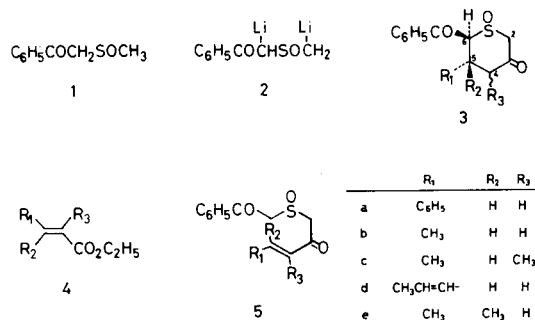
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$\beta$ -Monosubstituted  $\alpha,\beta$ -unsaturated esters undergo an annulation with dilithio salt of  $\omega$ -(methylsulfinyl)acetophenone to produce 5-substituted 6-benzoylthian-3-one 1-oxides.

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It is well known that the  $\alpha,\beta$ -unsaturated esters undergo an annulation with acetoacetic ester to afford cyclohexane-1,3-dione derivatives under base-catalyzed conditions (1,2). The reaction is realized to proceed *via* a Michael addition of the carbanion of acetoacetic ester to  $\alpha,\beta$ -unsaturated ester followed by an intramolecular Claisen condensation of the resulted intermediate. On the other hand, the reactions of acrylic ester with  $\beta$ -ketosulfoxides such as  $\omega$ -(methylsulfinyl)acetophenone (**1**) afforded only Michael adducts, but gave no such annelated product as thian-3-one 1-oxide **3** under a variety of base-catalyzed conditions (3-6). In the course of our studies on the chemistry of the dianion of  $\beta$ -ketosulfoxide (**7**), we found a novel type of annelation to produce a range of thian-3-one 1-oxides **3**, which involves an acylation of the dianion **2** of **1** at its terminal carbanion with  $\alpha,\beta$ -unsaturated ester followed by an intramolecular Michael addition of the intermediary monoanion of unsaturated diketosulfoxide **5**. The mode of this reaction is in sharp contrast to that of the dianion of  $\beta$ -dicarbonyl compounds; *i.e.*, cinnamic ester undergoes an acylation and/or a Michael addition with the dianion of acetoacetic ester or benzoylacetone at their terminal carbanion, but affords no such annelated product as cyclohexane-1,3-diones (**8**).

Scheme



The dianion **2** was generated by treatment of  $\omega$ -(methylsulfinyl)acetophenone (**1**) with slight excess of two molecular equivalents of *n*-butyllithium in tetrahydrofuran at  $-78^\circ$  (**7**). When one half equivalent of ethyl cinnamate

(**4a**) was added to a solution of the dianion **2** in tetrahydrofuran, and then the reaction mixture was allowed to warm to room temperature, a facile reaction occurred. The annelated product, 6-benzoyl-5-phenylthian-3-one 1-oxide (**3a**), was obtained in 68% yield based on ethyl cinnamate after purification on silica gel. Under the same reaction conditions the  $\alpha,\beta$ -unsaturated esters **4b**, **4c**, and **4d** also reacted with the dianion **2** to produce the corresponding thian-3-one 1-oxide derivatives **3b**, **3c**, and **3d** in yields of 50, 58, and 61%, respectively. The structures of **3a-d** were confirmed by elemental analyses and the spectral data (see Experimental). The assignments for the signals of nmr spectra were further supported by deuterium labeling experiment. The stereochemistry of H-5 and H-6 was assigned on the basis of the spin coupling pattern (9-10 Hz).

When equimolar equivalent of  $\alpha,\beta$ -unsaturated ester **4** was used in these reactions, the yield was extremely lowered. Thus, the reaction with ethyl cinnamate gave only 30% yield of **3a**. This result is in agreement with the case of an acylation of the dianion **2** (or other dianions (**8**)) with ethyl benzoate, where only one half amount of ethyl benzoate takes part in the reaction. This is presumably because the proton transfer occurs from the acylated product to the remaining dianion under the progress of the reaction. In the present case, if the proton transfer occurred from the monoanion of **5** to the dianion **2**, the subsequent annelation would not take place since the enone moiety of the resulted dianion **5** was inactivated by the neighboring carbanion. It can therefore be presumed that the intramolecular Michael addition occurred rapidly after the initial acylation of the dianion **2** and the proton transfer occurred from the monoanion of **3** to the dianion **2**.

An intramolecular Michael addition is subject to steric hindrance. Thus, the reaction of ethyl senecioate **4e** with the dianion **2** gave only the diketosulfoxide **5e** in yield of 54%, but afforded no annelated product (**9**).

The present method for the construction of thian-3-one 1-oxide rings is of preparative value in view of the tedious methods so far employed for the preparation of such compounds (10,11).

## EXPERIMENTAL

All melting points are uncorrected. Ir spectra were recorded with a Hitachi EPI-G2 spectrophotometer in potassium chloride disks. Nmr spectra were recorded on a Hitachi R-22 spectrometer (90 MHz) using tetramethylsilane as an internal standard with deuteriochloroform as a solvent, and chemical shift ( $\delta$ ) are given in ppm relative to tetramethylsilane. Mass spectra were obtained on a Hitachi RMU-6D with a direct inlet system operating at 70 eV.

6-Benzoyl-5-phenylthian-3-one 1-Oxide (**3a**).

Dry tetrahydrofuran (ca. 70 ml.) was distilled from lithium aluminum hydride into a 100-ml. flask containing 400 mg. (2.2 mmoles) of  $\omega$ -(methylsulfinyl)acetophenone (**1**). The flask was stoppered with a septum cap, flushed with argon, and cooled in a dryice-acetone bath. Then 2.9 ml. of 1.59 M (4.6 mmoles) of *n*-butyllithium in hexane was added dropwise (via syringe) with stirring. After stirring for additional 20 minutes, 194 mg. (1.1 mmoles) of ethyl cinnamate was added and the reaction mixture was allowed to warm to room temperature during 1 hour with stirring. The reaction was quenched by the addition of 10 g. of wet silica gel (70-230 mesh), which was removed by filtration. The solvent was evaporated off, and the residue was chromatographed on silica gel, using ethyl acetate as an eluent, to give 233 mg. (68%) of **3a**, m.p. 156-157° (benzene); ir: 1720 (ketone), 1680 (ketone), and 1060 (sulfoxide)  $\text{cm}^{-1}$ ; nmr:  $\delta$  2.82 (1H, dd, H-4, J = 17 and 3 Hz), 3.52 (1H, dd, H-4, J = 17 and 13 Hz), 3.98 (1H, ddd, H-5, J = 13, 10 and 3 Hz), 4.02 (2H, s, H-2), 4.92 (1H, d, H-6, J = 10 Hz), and 7.2-7.8 (10H, m, arom); ms: m/e 312 ( $\text{M}^+$ ).

Anal. Calcd. for  $\text{C}_{18}\text{H}_{16}\text{O}_3\text{S}$ : C, 69.21; H, 5.16. Found: C, 69.71; H, 5.18.

Deuteration of **3a**.

A solution of 40 mg. of **3a** in 0.3 ml. of deuteriomethanol-*d*<sub>4</sub> was warmed to 50-60° for several minutes and the solvent was removed by evaporation. Three times repetition of this procedure afforded deuterated compound, whose nmr spectrum clearly indicated the absence of the signals due to H-2 and H-6 at  $\delta$  4.02 and 4.92, respectively.

6-Benzoyl-5-methylthian-3-one 1-Oxide (**3b**).

By the procedure described above for the preparation of **3a**, compound **3b** was obtained from 125 mg. (1.1 mmoles) of ethyl crotonate (**4b**) in a yield of 50% (138 mg.), m.p. 137-140° (benzene); ir: 1710 (ketone), 1680 (ketone), and 1040 (sulfoxide)  $\text{cm}^{-1}$ ; nmr:  $\delta$  1.16 (3H, d,  $\text{CH}_3$ , J = 6 Hz), 2.53-3.13 (3H, m, H-4 and H-5), 3.94 (2H, s, H-2), 4.59 (1H, d, J = 9 Hz), and 7.4-8.1 (5H, m, arom); ms: m/e 250 ( $\text{M}^+$ ).

Anal. Calcd. for  $\text{C}_{13}\text{H}_{14}\text{O}_3\text{S}$ : C, 62.38; H, 5.64. Found: C, 62.21; H, 5.59.

6-Benzoyl-4,5-dimethylthian-3-one 1-Oxide (**3c**).

By the procedure described above for the preparation of **3a**, compound **3c** was obtained from 141 mg. (1.1 mmoles) of ethyl tiglate (**4c**) in a yield of 58% (168 mg.), m.p. 190-192° (benzene); ir: 1705 (ketone), 1665 (ketone), and 1040 (sulfoxide)  $\text{cm}^{-1}$ ; nmr:  $\delta$  1.12 (3H, d,  $\text{CH}_3$ , J = 6 Hz), 1.21 (3H, d,  $\text{CH}_3$ , J = 6 Hz), 2.31-2.91 (2H, m, H-4 and H-5), 3.96 (2H,

s, H-2), 4.70 (1H, d, H-6, J = 9 Hz), and 7.4-8.1 (5H, m, arom); ms: m/e 264 ( $\text{M}^+$ ).

Anal. Calcd. for  $\text{C}_{14}\text{H}_{16}\text{O}_3\text{S}$ : C, 63.61; H, 6.10. Found: C, 63.45; H, 6.13.

6-Benzoyl-5-(1-propenyl)thian-3-one 1-Oxide (**3d**).

By the procedure described above for the preparation of **3a**, compound **3d** was obtained from 154 mg. (1.1 mmoles) of ethyl sorbate (**4d**) in a yield of 61% (185 mg.), m.p. 154-155° (benzene); ir: 1715 (ketone), 1665 (ketone), and 1040 (sulfoxide)  $\text{cm}^{-1}$ ; nmr:  $\delta$  1.53 (3H, d,  $\text{CH}_3$ , J = 6 Hz), 2.53-3.03 (2H, m, H-4), 3.20-3.55 (1H, m, H-5), 3.93 (2H, s, H-2), 4.67 (1H, d, H-6, J = 9.5 Hz), 5.27-5.75 (2H, m,  $-\text{HC}=\text{CH}-$ ), and 7.5-8.0 (5H, m, arom); ms: m/e 276 ( $\text{M}^+$ ).

Anal. Calcd. for  $\text{C}_{15}\text{H}_{16}\text{O}_3\text{S}\cdot\text{H}_2\text{O}$ : C, 61.20; H, 6.16. Found: C, 61.29; H, 6.10, similar values were obtained in another run, C, 60.91; H, 6.00.

4-Methyl-1-(phenacylsulfinyl)pent-3-en-2-one (**5e**).

Compound **5e** was obtained by the same procedure as described for the preparation of **3a** from 141 mg. (1.1 mmoles) of ethyl senecioate (**4e**) in a yield of 54% (157 mg.), m.p. 82-83° (benzene); ir: 1670 (ketone), 1610 (olefin), and 1040 (sulfoxide)  $\text{cm}^{-1}$ ; nmr:  $\delta$  1.92 (3H, d, J = 1 Hz), 2.17 (3H, d, J = 1 Hz), 3.98 (2H, ABq, J = 14 Hz), 4.52 (2H, ABq, J = 14 Hz), 6.12-6.18 (1H, m), and 7.35-8.0 (5H, m); ms: m/e 264 ( $\text{M}^+$ ).

Anal. Calcd. for  $\text{C}_{14}\text{H}_{16}\text{O}_3\text{S}$ : C, 63.61; H, 6.10. Found: C, 63.56; H, 6.10.

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